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LIVE/VIRTUAL SEAMLESS SIMULATION

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ABSTRACT (CONT)

RFPI invented and incorporated a suite of concepts, models, tools and instrumentation to achieve its objectives, and demonstrated their integrated capability in this experiment. One example of a novel concept is a "Split Functionality" approach, where the existence and functionality of live tactical entities were represented, or "shadowed," in simulation. Multiple simulation machines were used to execute subsets of the overall functionality of a single given entity. Split functionality permitted live/virtual interactions to occur more realistically, and in real-time. This report addresses the requirements that drove this design and in greater detail, the implementations used to accomplish this effort.

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I. OBJECTIVES

The objective of the Rapid Force Projection Initiative (RFPI) Advanced Concept Technology Demonstration (ACTD) was to enhance the Lethality and Survivability and to increase the Battle Tempo of Light Early Entry Forces using advanced technology fieldable prototype systems. The RFPI program used a system of advanced technology systems to accomplish this goal and demonstrated their performance in a large scale Field Experiment held at Fort Benning, Georgia, in the fourth quarter of FY98. This Field Experiment was a Division Ready Brigade (DRB) against a heavy Motorized Rifle Division (MRD) sized Opposing Force (OPFOR). Due to the usual size, budget, and other resource limitations, this Field Experiment was implemented as an Advanced Distributed Simulation (ADS) with live and virtual entities participating and interacting together. Large-scale live/virtual exercises have been performed before; however, our approach to this challenge established several new techniques and tools for accomplishing a seamless interface between the two environments.

II. WHAT MADE THIS EXPERIMENT DIFFERENT FROM OTHERS?

There are three classical approaches to doing ADSs as shown in Figure 1. Each is suited to a particular set of conditions. They do share one aspect; however, they preclude or at least minimize live/virtual interactions, especially at the lower unit or element levels. In the Training oriented approach, live entities engage live entities and virtual entities engage virtual entities, typically separated by terrain features, eliminating the requirement for detections or engagements across the live/virtual boundary. In the Demonstration approach, live element participation is held to a minimum with simulation used to “fill out” to upper portions of the organization. In the Stimulation approach, the live/virtual boundary is set to isolate upper echelons from the lower echelons – a typical Command Post Exercise (CPX) configuration. Because of the variety of RFPI elements that operated at all echelons, along with real-world practical considerations, the RFPI DRB (Fig. 2) is not as “clean” as might usually be the case. It is a mix of real and simulated units and elements throughout. With the force facing a Division-sized OPFOR of which 90+ percent existed in simulation, it was imperative that we be able to cross the live/virtual boundary as an integral part of the exercise, and to do so with a minimum of restriction.

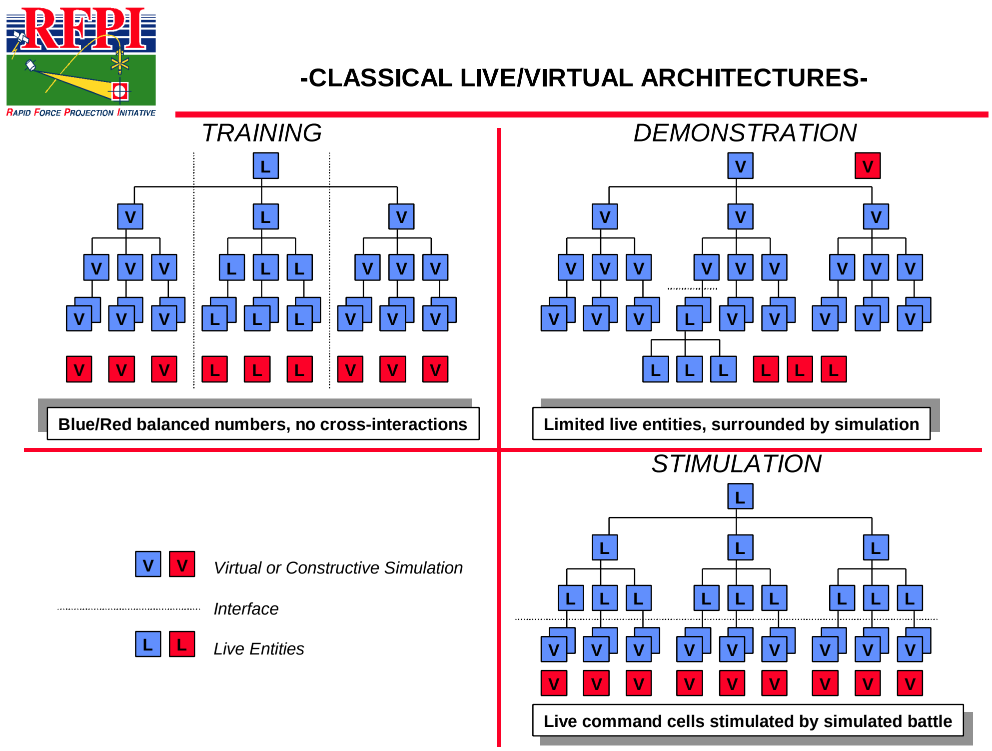

Figure 1. Classical Live/Virtual Architectures

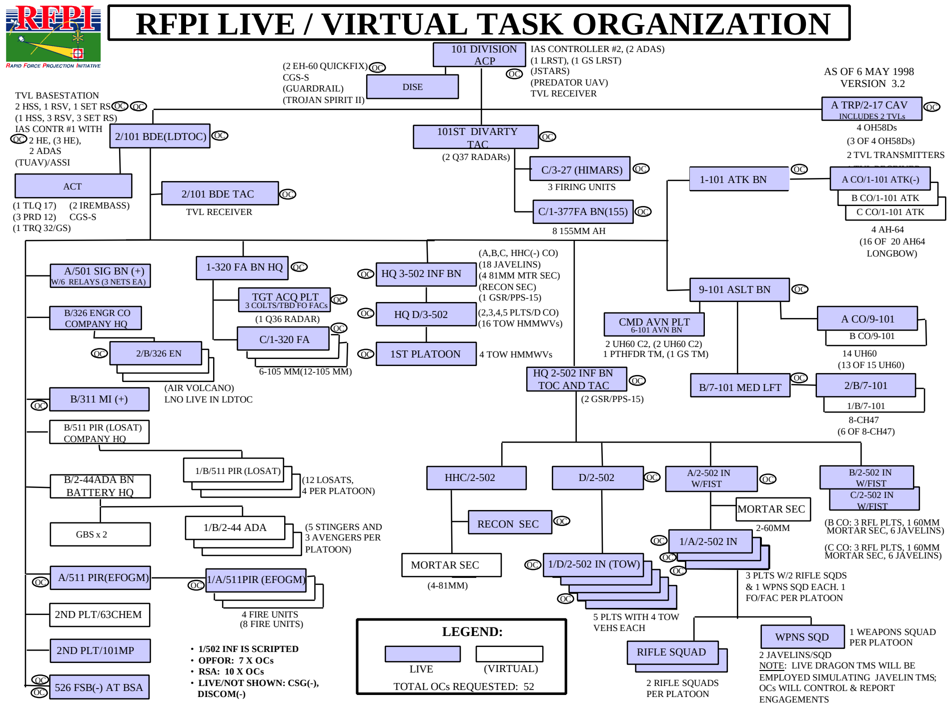

Figure 2. The RFPI Live/Virtual Structure

Over the course of four years, RFPI developed a combined live/virtual/constructive simulation architecture through the execution of a series of interim experiments and integration tests. The evolution of the architecture allowed critical development to progress methodically and concurrently with RFPI system definitions and advances in off-the-shelf simulation technology, and trained a cadre of experts in the field of virtual simulation experimentation. The RFPI simulation architecture was explicitly designed to support the live/virtual/constructive constraints of the Field Experiment, and could not be fully demonstrated until all live elements and personnel were on the ground. In the final configuration, the simulation architecture supported the following objectives in real-time:

(1) Expand the live fight to Blue DRB versus Red Division

- Represent entire compliment of live/virtual/constructive entities in the virtual domain

(2) Enable interaction of live/virtual/constructive entities

- Represent all munitions firing, detonations, and casualties in virtual domain
- Inform live entities of their damage status
- Reflect direct-fire MILES casualties in virtual domain
- Synchronize live and virtual target acquisitions and Battle Damage Assessment (BDA)
- Transition one virtual battalion of OPFOR to live OPFOR at range boundary
- Interface with live OPFOR voice nets

(3) Stimulate Division and Brigade C4I

- Represent critical virtual Operational Facilities (OPFACs) to participate on tactical voice networks
- Represent critical virtual OPFACs to participate on tactical digital networks
- Stimulate Army Tactical Command & Control Systems (ATCCS) to the degree supported by existing stimulation tools

(4) Support exercise control, data collection, and analysis

- Interface virtual environment O/Cs to live O/C voice network
- Accumulate and display battle views and statistics
- Integrate with Experiment Control and Instrumentation Control via voice and digital nets

The final RFPI Field Experiment architecture included a complex mix of live and virtual blue as well as red forces divided between 42 live systems (32 surrogate BMPs and 10 tanks) and the remainder of the fighting elements of a red division played virtually/constructively. This lopsided distribution of live and virtual blue and red forces is shown in Figure 3.

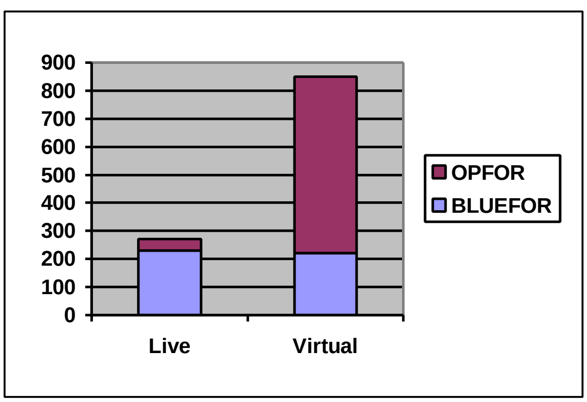

Figure 3. Red/Blue Live/Virtual Entity Counts

III. SEAMLESS TRUTH DATA

An additional complication was the size of the Fort Benning live maneuver area, which prohibited live OPFOR from being presented at the extended ranges where many DRB fire support and aviation assets engage. To support this requirement, 42 virtual OPFOR vehicles were transitioned to live vehicles at the Fort Benning range boundary as shown in Figure 4.

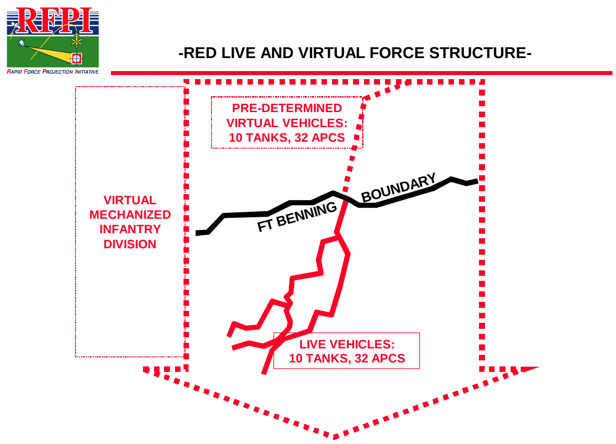

Figure 4. Virtual to Live Transition

The RFPI live Instrumentation and virtual simulation architecture that met these requirements was a Distributed Interactive Simulation (DIS) federation of models and tools. (Figs. 5 and 6).

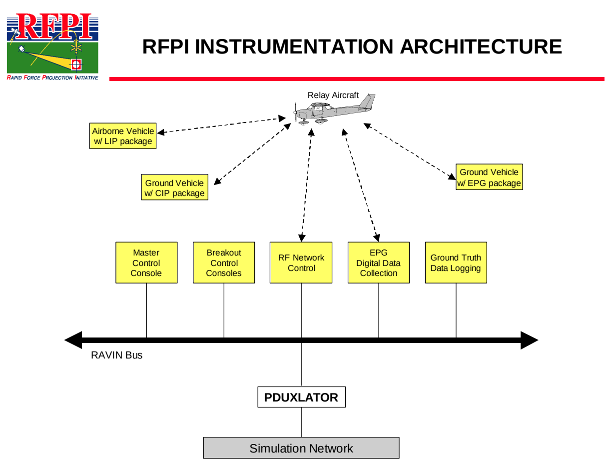

Figure 5. The RFPI Instrumentation Architecture

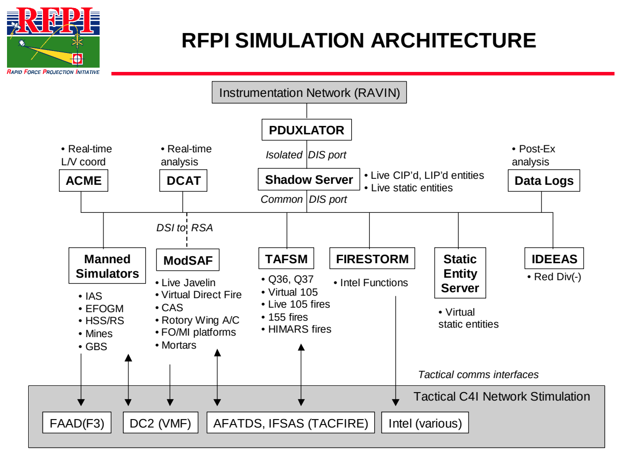

Figure 6. The RFPI Simulation Architecture

The architecture includes the following models and tools, interfaced across a DIS backbone:

1. The Real-time Acquisition Virtual Instrumentation Network (RAVIN) Instrumentation network is a 100 MHz bus based system with independent modules interfacing to and controlling the Live entity instrumentation RF network, the Digital Message Collection network, and logging all ground truth data. RAVIN collects the position and status data necessary for shadowing live entities in the Virtual environment and relays Casualty Assessment information from the Virtual environment back to the Live entity.

2. The Protocol Data Unit Translator (PDUXLATOR). RFPI developed this device to interface between the RTTC instrumentation network and the Shadow Server. It provided live position data in the form of a DIS entity state heartbeat, coordinated the state changes that occurred in the virtual domain with the live state, and officiated between ground truth and game truth. The tool maintained steady virtual position data, filtered out GPS dropouts, dead-reckoned position, and ground-clamped ground entities.

3. Shadow Server – This simulation was developed by RFPI as a modification to the Battlefield Environment Weapon System Simulation (BEWSS) developed at the U. S. Army Aviation and Missile Command (AMCOM) Aviation and Missile Research, Development, and Engineering Center (AMRDEC). This simulation performed the virtual functions for the live systems to support our split-functionality approach to live/virtual seamlessness. The shadow server performed acquisitions and engagements of virtual targets, vulnerability assessments, and state changes in the virtual domain on behalf of the live element. Role players at the Shadow Server stations coordinated virtual activities with their live counterparts across non-tactical and tactical voice networks so that virtual activity could be reported by live OPFACs across tactical channels.

4. Modular Semi-Automated Forces (ModSAF). This simulation was developed by Simulations, Training, and Instrumentation Command (STRICOM) and incorporated into the RFPI architecture in support of the mandate to standardize Semi-Automated Forces (SAFOR) across the army. RFPI developed several modules and refined some of the system characterizations and digital communications capabilities within this model, and has submitted those custom changes back to STRICOM for incorporation in their formal release system. RFPI used ModSAF to represent the bulk of blue ground and air systems.

5. Target Acquisition Fire Support Model (TAFSM). Fort Sill developed this simulation, and it is the standard tool used to represent artillery system play in constructive and virtual experiments throughout the Army. TAFSM was also used to fire the virtual munitions of all live indirect fire systems with the exception of Enhanced Fiber Optic Guided Missile (EFOGM), and to represent counter-battery radar systems.

6. Federation of Intelligence, Reconnaissance, Surveillance and Targeting, Operations and Research Models (FIRESTORM). FIRESTORM is a Ft. Huachuca model used to

stimulation tactical intelligence systems. RFPI used FIRESTORM to generate the simulated feeds from JSTARS, ASARS, Guardrail, QUICKFIX, TEAMMATE, AN/PRD-12, and TRAFFICJAM.

7. Static Entity Server (SES). This model was developed by RFPI to offload simplistic static system representations from more complex models. It instantiated the entity state PDUs and calculated vulnerability for static entities. It was used during the Field Experiment to represent primarily virtual tents, bunkers, and some CS/CSS elements.

8. Interactive Distributed Engineering Evaluation and Assessment Simulation (IDEEAS). The AMCOM Missile RDEC developed this model as a DIS version of the BEWSS constructive model. RFPI enhanced IDEEAS capability to allow more operator interaction and compatibility with ModSAF and other simulations. IDEEAS was used to represent the virtual OPFOR, and gave the OPFOR commander sufficient control to execute free play and respond to blue force actions.

9. Manned Simulators –

   a. Integrated Acoustic System (IAS). The live IAS controller station has internal virtual capability that was used to represent virtual IAS sensors for the Field Experiment.

   b. EFOGM. The EFOGM project office developed two manned simulators, which represented the virtual EFOGM platoons for the field experiment, using tactical missile flight software, tracking software, and C4I hardware and software.

   c. HSS/RS – Hunter Virtual Prototype System (HVPS). The HVPS represented two HSS and RS systems for the field experiment using two manned simulators, one at RSA, and one at Ft Benning. These simulators were developed by RFPI.

   d. Mines – Raptor Emulator. The Raptor Emulator was developed by RFPI for representation of the Intelligent Mine Field (IMF (Raptor)) in previous Battlefield Lab Warfighting Experiments (BLWEs). It was used as a surrogate for conventional minefields during the Field Experiment. It consisted of a single station at Redstone Arsenal, Alabama (RSA).

   e. GBS – Sentinel Simulator. The Sentinel project office developed this simulator. It was connected directly to a tactical Forward Area Air Defense (FAAD) device at Ft. Benning.

10. Appearance Change Monitor for Experiments (ACME). RFPI designed the ACME to support the manual coordination of non-instrumented live entities and their corresponding virtual state. ACME reported all kill types to the operator to relay to the Maneuver Control Cell, and also included a virtual God Gun so that MILES kills from the live domain, and administrative kills ordered by the Experiment Control Cell could be entered into the virtual state of individual systems.

11. Data Collection and Analysis Tool (DCAT). The AMCOM Missile AMRDEC developed this tool in support of RFPI's requirement for real-time performance data review and detailed analysis of PDU data logs. DCAT allows the creation of Measures of Effectiveness (MOEs) such as killer-victim scoreboards, shots, hits, kills, as well as distributions of events over time and range domains. DCAT was the primary tool used to determine approximate as-run performance during the Field Experiment.

12. Data Logs – Data logs are the definitive resource for post-experiment analysis of game truth, capturing every PDU on the network, and are used for data review and replay if the experiment events. Unique to the RFPI experiment in an event of this size, all live and constructive entity states and engagements were projected into the virtual environment and can be analyzed using the data logs. Data logs were collected at Ft. Benning and at RSA by simulation and data management personnel.

13. Tactical C4I Network Stimulation - The stimulation requirement for the simulation architecture was centered around the digital targeting process, but included legacy capabilities and some developments to further VMF situational awareness messaging. The stimulation capabilities provided were as follows:

    - SINCGARS voice links (duplex with commercial telephones and conference calls)
    - TFXXI VMF messages (simplex from ModSAF and duplex with manned simulators) via DIS signal PDUs routed through a Communications Processor
    - TACFIRE messages (duplex with TAFSM and ModSAF through the PIU connected to AFATDS and IFSAS)
    - FAADC2I F3 messages (simplex from the Sentinel simulator to FAAD)
    - Various Intel feeds from FIRESTORM to appropriate nodes.

The seamless functional design of the RFPI architecture is the primary discriminator between this experimental event and previous live/virtual demonstrations. The RFPI architecture allowed all combination of live and virtual, red and blue interactions, without artificial boundaries between units. This gave the blue force commander more freedom to fight the entire battle as he saw fit, including the demonstrated capability to air assault live and virtual reinforcing elements on command in support of a battle position. RFPI simulation invented a suite of concepts, models, and tools to accomplish this split-functionality, and demonstrated the integrated capability of the federation in this experiment.

IV. SPLIT FUNCTIONALITY

Most people involved in virtual simulations are aware of the concept of Selective Fidelity where a simulated entity has its various operational functions simulated with different levels of detail, depending on what impact that function has on the overall objective of the experiment. We took that concept and expanded it into what we called Split Functionality. Split Functionality is the assignment of portions of various operational functions of an entity to either the live or the virtual environment, depending on where it made sense. Specifically, we had individual entities that had representations in both the live and the virtual environments. Instrumentation was used to determine the position and status of the live entity. This information was passed through the RAVIN instrumentation integration node to the PDU Translator node. The PDU Translator acted as the gateway between the live and virtual environments and was the dividing line between Ground Truth and Game truth. The PDU Translator transmitted DIS Standard PDU's to the Shadow Server which performed all collision /casualty assessment for the live entities in the virtual environment. Should a live/shadowed entity experience a status change due to a casualty assessment (or any other reason), the Shadow Server notified the PDU Translator who in turn notified RAVIN, which relayed the status change to the entity in the field. Eight "Shadow Levels" were established to negotiate the live/virtual functional allocations for every specific system in the red and blue task organizations. These shadow levels are defined in the following Table.

Table. RFPI Live Entity Shadow Levels

					Functionality		
Level	**Entity Type**	**Instr.**	**Position Data**	**Coord w/shadow**	**Shooters**	**Sensors**	**Examples**
0	Stationary	No	Manual	O/Cs	N/A	N/A	Most TOCs
1	Moving	Yes	RAVIN	O/Cs	N/A	N/A	Instrumented C4I (EFOGM Plt Ldr)
2	Moving	Yes	RAVIN	O/Cs	TAFSM or ModSAF	N/A	Most Shooters
3	Moving	Yes	RAVIN	Direct	N/A	Shadow Server	Manned Sensors
4	Stationary	No	Manual	O/Cs	Live on Live = MILES Live on Virtual = ModSAF	Live by Live as normal Live by Virtual = ModSAF	Infantry Company Commanders
5	Moving	Yes	RAVIN	O/Cs	Live on Live = MILES Live on Virtual = Shadow Server	Live by Live as normal Live by Virtual = ModSAF	TOW Vehicles
6	EFOGM	Yes	RAVIN	Direct	Shadow Server does BDA	Custom Mission Interface	EFOGM Fire Units
7	Aviation	Yes	ModSAF tethers to RAVIN shadow	O/Cs	ModSAF	ModSAF	Helicopters

With this configuration, if a live Target presented itself, the live Sensor would detect the target. Should a virtual target be presented, the Shadow version of the live Sensor would detect the target and pass the acquisition information to the live sensor for appropriate action. This implementation required the operators of the live and virtual copies of the same entity to be able to coordinate with each other. It also meant that we in the control node had to monitor OPFOR operations to insure that a live Target and a virtual Target did not “come over the hill” at the same time.

V. COORDINATION ARCHITECTURE

With the new concept of Split Functionality comes the requirement to coordinate between those multiple instances of the same entity. While live entities were watching for and engaging live enemy entities and their Shadows were watching for and engaging virtual enemy entities, we provided a non-tactical direct radio channel between the live and Shadow operators of the "same" entity. Operations procedures were as follows: If the live operator detected a target, the live operator would use their tactical radios to report that target (normal operations). If the Shadow operator detected a target, they would use the direct radio channel to inform the live operator that there was a target at location "X." The live operator would then use the tactical communications nets to make the target report.

Because of our architecture, multiple Tactical Communications nets were required to cross the live / virtual interface and be available for use in both environments. We used two RedCom Laboratories IGX Switch boxes with SINCGARS radio interface cards manufactured by Diversified Products, International. These gave us the capability of having a conference telephone call in the virtual environment directly interfaced to a SINCGARS radio net in the live environment. The two racks were physically located at two different locations at Fort Benning in order to have the "base station" closer to the actual radio net to reduce range issues. These interfaces are depicted in Figure 6 as the "Tactical Comms Interfaces."

As shown in Figure 6, we had a category of non-instrumented (Static) entities that were manually entered into the virtual environment. For those entities, coordination across the live/virtual interface was done manually using two tools we developed for this effort. The Appearance Change Monitoring Entity (ACME) monitored the virtual environment and if a Static entity had a status change due to being engaged, the ACME would inform the operator of this fact. The ACME operator would then relay the fact that entity "X" had been killed (for example) to the RFPI Field Experiment Observer / Controller (O/C) control node. The control node would relay to the appropriate O/C for them to go to the entity and use their O/C Control Gun to set off the entity's MILES equipment. Conversely, if the O/C radioed in that entity "Y" had suffered a MILES Kill, then the ACME operator could use our other tool, the virtual God Gun, to effect the kill of the entity in the virtual environment.

VI. GROUND TRUTH VERSUS GAME TRUTH

The requirement for keeping separate “truth’s” regarding entity position comes from several areas such as: when an entity “dies”, it should stop moving immediately (Game Truth) but in reality, time delays, hardware failures, operator inattention, etc. could result in the entity continuing to move for some time. Ground Truth allows the instrumentation personnel to see the entity continuing to move and to do something to stop the vehicle motion. Also, aircraft when they “die” crash to the ground (Game Truth) while in reality when notified of their demise the aircraft should return to base and land (Ground Truth). In our architecture, the PDU Translator was the boundary line between Ground Truth and Game Truth. Monitoring a console in the RAVIN system showed the Ground Truth about a vehicle's location and motion while monitoring a similar console in the virtual environment showed the Game Truth and showed dead entities at the point of their demise.

VII. LESSONS LEARNED

The degree of interaction of live/virtual/constructive entities allowed by this architecture, and the inherent ability to remotely link this capability with non-instrumented ranges has never before been achieved, and does not exist elsewhere in the army or DOD simulation communities. The 101^{st} Division has expressed an interest in using this capability in support of training events during the RFPI residual period, and the DBBL has expressed an interest in incorporating elements of this architecture in the JCF AWE. Delay in the re-use of this capability may place the RFPI simulation accomplishments in the same category as NASA’s Apollo missions in terms of affordability once the desire to repeat the event is realized.

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